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Proving Electric Conductors, &c.

LETTERS PATENT to Cromwell Fleetwood Varley, of No. 4, Fortess Terrace, Kentish Town, & Cornelius John Varley, of No. 7, York Place, Kentish Town, St. Pancras, Middlesex, for the Invention of "Improvements in Proving Electric Conductors, & in the Apparatus connected therewith."

Sealed the 13th December 1859, and dated the 23rd June 1859.

PROVISIONAL SPECIFICATION left by the said Cromwell Fleetwood Varley and Cornelius John Varley at the Office of the Commissioners of Patents, with their Petition, on the 23rd June 1859.

We, Cromwell Fleetwood Varley, of No. 4, Fortess Terrace, Kentish Town, & Cornelius John Varley, No. 7, York Place, Kentish Town, St. Pancras, Middlesex, do hereby declare the nature of the said Invention for "Improvements in Proving Electric Conductors, & in the Apparatus connected therewith," to be as follows:—

The chief object of our Invention is to find out the locality of defects in the insulation of a conductor or imperfect continuity of the latter without removing the covering or the insulator, or cutting the conductor for testing. We generally first ascertain approximately the locality of the fault by the following new method. For example, suppose the defective conductor to be a cable in the maker's stores & under water, we pass the current from a voltaic battery through the two wires of a differential galvanometer in opposite directions, one pole of the battery being connected with the earth or water, & the two ends of the wires from the differential galvanometer connected with the two ends

of the conductor whose insulation is defective, the current from the battery divides & goes round the galvanometer in opposite directions, & entering both ends of the cable escapes at the defect in the insulator. If this defect is equidistant from the two ends the resistance will be equal, the currents round the galvanometer will be equal, & the needle will stand at zero. If the fault be not in the middle the resistance will be unequal, the shorter route will allow the passage of more electricity than the other, & the needle will be deflected, we now introduce a rheostat into the shorter circuit, & introduce so much resistance as shall make the two portions equal in resistance, having noted this, & the resistance of the whole conductor, the following formula will show very nearly the exact locality of the defect:—

Resistance of the whole conductor	$= S$	then
„ of longer portion	$= x$	$x + y = S$
„ of shorter portion	$= y$	$x = y + r$
„ of rheostat	$= r$	$\dfrac{S - r}{2} = y$

The peculiarity of this mode of testing is that the ever varying resistance of a damp fault does not affect the result. This operation is not always used, especially when the cable is short; having ascertained the approximate locality as before, the actual spot is found by our second improvement. When a current of electricity is flowing through a conductor it produces magnetic influence or rays throughout the length, & outside of the conductor; if the conductor be coated partially or wholly with iron, the iron becomes magnetized to a certain degree. We apply outside the conductor coils of wire, iron bars, or horse-shoes wrapped with wire, to be acted on by the magnetic power of the current in the conductor, & every time the current in the conductor flows or ceases to flow, or is reversed, the magnetism is disturbed, & weak electric currents are thereby induced in these coils, bars, or horse-shoes, which we term probes, & the latter currents are render'd visible by delicate galvanometers. We generally employ a reversing apparatus similar in principle to that first invented & patented by C. F. Varley in 1854, for working printing telegraphs, we cause alternating or intermittent currents to enter one end of the cable & escape at the leak, or we cause currents to enter both ends, but at different rates of alternation or intermission. In the latter case on applying our probes outside the conductor, we see immediately by the speed of the deflections on which side of the fault the probe is; the probes are then moved along the cable towards the leak until by the varying speed of the deflections we discern that the fault has been passed. When the intermittent or alter-

nating currents are applied to one end only of the cable, the other end of the cable is insulated, the currents then run along the conductor to the fault & there escape, our probes then show by the existence or non-existence of currents in their coils on which side of the fault they are. Having traced out the locality of the fault, a Spanish windlass is made, or the cable is cut at the spot repair'd, & spliced as usual. Thus, by a single cut or splice the fault is removed. Hitherto to find such a fault it has been necessary to cut & splice the cable in many places before the locality of the fault was traced out.

A splice takes from two to ten hours to make, & frequently wastes from twenty to thirty feet or more of cable, besides causing great delay, & expense, & injury to the cable. When the defect is a break in the conductor, we first pass powerful currents from an induction coil or coils; these currents leap across the break in the conductor, & there & there only produce great heat, which melts the insulator, & so causes defective insulation at this spot. This effected, we proceed as in the former case. When the defect is a very small one, giving great resistance, the induction coil is used to burn it open, & thus admit the water & give free vent to the electricity, we then proceed as before. When the conductor under examination is simply a wire coated with an insulator, & the conductor is broken, we apply currents of considerable tension to one end of the wire, & place an insulated conductor of electricity such as metal tubes, foil, or place a portion of the wire under examination in a basin of water insulated, the charge entering the wire acts by electric induction on the outer tube, foil, or water, which latter acts the part of the outer coating of a Leyden jar, this outer coating is connected with one of two conductors that are very near each other in a highly exhausted receiver, the other conductor is connected with the earth. The induced electricity will then be seen to pass between the two conductors, this outer covering is then moved along the insulated conductor, & the moment it has passed the fault where the inside tension terminates, the light in the vacuum ceases & indicates that the defect has been passed, or we use any of the well known instruments for indicating the presence of small portions of electricity. When it is desirable not to damp the insulated wire containing a defect in the insulation, we put the whole coil into a large receiver & exhaust to a nearly perfect vacuum, then on causing currents to enter one end of the wire, they escape at the defect through the rarified air to the pump plate, & thus indicate at once, by their luminosity, the exact locality of the fault.

For the purpose of making the exhaustions it became requisite to have a pump that cou'd absolutely be always depended on for readily producing a sufficiently perfect vacuum, & as the ordinary air-pumps do not give such a

vacuum for these tests, & are always liable to become leaky, we have constructed the following which gives with certainty the required vacuum, & is very little liable to derangement by use.

The peculiarities of this pump are that mercury is used above the piston, the valves, & the joints, to keep all air-tight, & which by filling the space below the piston on its descent perfectly excludes all the air & moisture, hence it is able to pump out condensable vapour, a circumstance that greatly promotes the exhausting power. The valves are lifted mechanically, & the whole so arranged that all is easily comeatable for cleaning.

In testing for a defect when out at sea great difficulty is experienced from the motion of the ship & the feebleness of the currents. We obviate much of this by supporting the galvanometer or indicator on a table of the following construction :—On the point at the top of a very heavy pendulum, whose vibrations are rapid, we mount a heavy table on its center of gravity; this is so connected by a spring or springs to the pendulum, that it maintains a position the mean between all the vibrations; on this table we mount our galvanometer.

When an astatic galvanometer is used of slow oscillation, we alternate the connections of the galvanometer with the probes at such a rate as to cause many or all of the alternating currents from the probe to pass round the galvanometer in one direction, & thus amplify the deflections. At sea or at a distance this is done by clocks or pendula, one at the end of the conductor to alternate or intermit the currents, the other with the probe to reverse the connections between the probe & its galvanometer; these clocks or pendula do not keep exactly the same time, & thus a series of currents are caused to flow in the same direction round the galvanometer, & so amplify the deflection, & as the pendula do not keep quite the same time, the galvanometer slowly oscillates from side to side. At sea we prefer the reflecting galvanometer, & generally use two exactly alike in construction, but connected in reversed directions, so that the swinging affects both mirrors alike, while currents are indicated by the approaching to or receding from each other of the two reflected spots. These needles are made more or less astatic by bringing a large magnet near to them to neutralize the earth's magnetism, or any other suitable means are adopted. When a conductor is broken, & we wish to ascertain the approximate distance of the break without burning open the insulator, or where this cannot be done we measure the distance by the amount of induction in the following new way:—A rheostat or bobbins of resistance are prepared free from magnetic induction or retardation; this we effect by winding the rheostat with two or more wires or a doubled wire, &

cause the currents to flow in opposite directions round them an equal number of times; this removes the momentary irregularity of their resistance. We prepare also a series of induction plates, whose action is similar to that of extensive Leyden jars of known & suitable dimensions; these induction plates are added to the coils of the rheostat, so as to give them induction corresponding in amount to that of an equal length of cable. The following example will explain their use:—Suppose a wire broken in the gutta percha, & thereby insulating perfectly by passing the current of a battery round the wires of a differential galvanometer, as much resistance & corresponding induction surface are added as shall produce equilibrium. This measures with tolerable precision the amount of induction or charge & discharge of the cable, & consequently the distance of the leak in the conductor. This can also be used to test the locality of a defect which gives great resistance but not complete insulation, as before assumed. As these induction plates are bulky, we prefer winding our differential galvanometer with many wires; we then connect the cable to one wire, but the rheostat to many; in this case the the resistance of the latter is increased in proportion, while the surface of the induction plates is reduced & render'd less cumbersome & expensive.

Our clocks or pendula used for alternating, &c., the currents, are sometimes arranged to send the intermittent currents for a few minutes, then disconnect the wire or put it to earth, or both, for testing, thus enabling us, after finding the particular wire & the locality of the fault, to test the insulation & conductivity of the remainder of the wire.

We do not confine ourselve to the exact form of apparatus described, nor to their application to any particular kind of conductor. These probes may also be used for picking out of a number of wires the one sought without injuring the insulation of any of them. This is of particular use in tunnels. We sometimes test our wire by exhausting it, then letting in water or acidulated water, &c., to the exhausted wire, &, lastly, the pressure of the atmosphere; this finds out many small faults otherwise not visible.

SPECIFICATION in pursuance of the conditions of the Letters Patent, filed by the said Cromwell Fleetwood Varley and Cornelius John Varley in the Great Seal Patent Office on the 22nd December 1859.

TO ALL TO WHOM THESE PRESENTS SHALL COME, we, Cromwell Fleetwood Varley, of No. 4, Fortess Terrace, Kentish Town, and Cornelius John Varley, of No. 7, York Place, Kentish Town, St. Pancras, Middlesex, send greeting.

WHEREAS Her most Excellent Majesty, Queen Victoria, by Her Letters Patent, bearing date the Twenty-third day of June, in the year of our Lord One thousand eight hundred and fifty-nine, in the twenty-third year of Her reign, did, for Herself, Her heirs and successors, give and grant unto us, the said Cromwell Fleetwood Varley and Cornelius John Varley, Her special licence that we, the said Cromwell Fleetwood Varley & Cornelius John Varley, our executors, administrators, and assigns, or such others as we, the said Cromwell Fleetwood Varley and Cornelius John Varley, our executors, administrators, and assigns, should at any time agree with and no others, from time to time, and at all times thereafter during the term therein expressed, should and lawfully might make, use, exercise, and vend, within the United Kingdom of Great Britain and Ireland, the Channel Islands, and Isle of Man, an Invention for "IMPROVEMENTS IN PROVING ELECTRIC CONDUCTORS, AND IN THE APPARATUS CONNECTED THEREWITH," upon the condition, (amongst others), that we, the said Cromwell Fleetwood Varley and Cornelius John Varley, our executors or administrators, by an instrument in writing under our or one of our, or their, or one of their hands and seals, should particularly describe and ascertain the nature of the said Invention, and in what manner the same was to be performed, and cause the same to be filed in the Great Seal Patent Office within six calendar months next and immediately after the date of the said Letters Patent.

NOW KNOW YE, that I, the said Cromwell Fleetwood Varley, on behalf of myself and of the said Cornelius John Varley now deceased, do hereby declare the nature of our said Invention, and in what manner the same is to be performed to be particularly described and ascertained in and by the following statement and accompanying Drawings, that is to say:—

The chief object of our Invention is to find out the locality of defects in the insulation of a conductor, or imperfect continuity of the latter, without removing the covering or the insulator, or cutting the conductor for testing. We generally first ascertain approximately the locality of the fault by the following method:—For example (vide Fig. 1), suppose the defective conductor to be a cable in the maker's stores, and under water; we pass the current from a voltaic battery C, Z, through the two wires of a differential galvanometer g in opposite directions, one pole of the battery being connected to the earth or water, and the two ends of the wires from the differential galvanometer g connected with the two ends of the conductor at S, S, whose insulation is defective. The current from the battery divides and goes round the galvanometer in opposite directions, and, entering both ends of the cable escapes at the defect in the insulator. If the defect is equidistant from the two ends, i. e. at B, the resistance will be equal, the currents round the galva-

nometer will be equal, and the needle will stand at zero. If the fault be not in the middle of the cable, but located at l, the resistance will be unequal, the shorter rout y will allow the passage of more electricity than the other x, and the needle will be deflected. We now introduce a rheostat r into the shorter circuit y, and add so much resistance as shall make the two routes indicated by the arrows equal in resistance. Having noted this, and the resistance of the whole conductor, the following formula will show very nearly the exact locality of the defect:—

Resistance of the whole conductor $= S$	then
,, of longer portion $= x$	$x + y = S$
,, of shorter portion $= y$	$x = y + r$
,, of rheostat $= r$	$\frac{S - r}{2} = y$

The peculiarity of this mode of testing is, that the ever varying resistance of a damp fault does not affect the result. The arrows indicate the supposed direction of a negative current, for ease of explanation, N.B. as a negative current, both attracts moisture to the fault, and keeps the metallic surface in an unoxidised state. It is nearly always the best current to use for testing. A positive current causes the resistance at l frequently to vary very much, owing to its oxydising action. This operation is not always used, especially when the cable is short.

Having ascertained the approximate locality, the actual spot is found by our second improvement, which we call probes, vide Figs. 2, 3, and 4. Fig. 2 is a side view of one of our forms of probes, containing a portion of a cable under test; Figs. 3 and 4 are end views and sections. *a* represents a portion of cable containing five wires, the five conducting wires being covered with gutta percha, hemp, and iron, as usual; *b*, a saddle-shaped piece of soft iron wrapper with insulated copper wire *c*; *d*, Figs. 2 and 3, flat bars or plates of iron fitting against the flat surfaces of *b* at *e*, *e*; these should be fitted accurately. *f* and *g*, the two ends of the wire coil *c*; *h*, Figs. 3 and 4, shows a protecting lining for the wire *c*. Fig. 4 shows another form of probe, in which two saddles of iron *b*, *b*, are used, fitting against each other, united by hinges, the pin at one side being withdrawn, to open or to close them securely when re-inserted. When a current of electricity is flowing through a conductor, it produces magnetic influence or rays throughout the length and outside of the conductor, we apply outside the cable *a*, *a*, our probes, consisting of coils of wire, iron bars, or horse-shoes wrapped with wire, as above described, to be acted on by the magnetic power of the current in the

conductor. Every time a current runs through the conductor, or ceases to flow or is reversed, the magnatism in the probe is disturbed, generating weak electric currents in the coils *c* of the probes. These weak currents are rendered visible by a delicate galvanometer, which is included in the circuit. We generally employ a reversing apparatus similar in principle to that first invented and patented by Cromwell Fleetwood Varley in 1854, for working printing telegraphs. We cause alternating or intermitting currents to enter one end of the cable, and escape at the leak, or we cause currents to enter both ends, but at different rates of alternation or intermission; in the latter case, on applying our probes outside the conductor, we see immediately by the speed of the deflections on which side of the fault the probe is. The probe or probes are then moved along the cable towards the leak until, by the varying speed of the deflections, we discern that the fault has been passed. When the intermittent or alternating currents are applied to one end only of the cable the other end is insulated; the currents then run along the conductor to the fault, and there escape. Our probes then show, by the existence or non-existence of currents in their coils, on which side of the fault they are. Having traced out the locality of the fault, a Spanish windlass is made, or the cable is cut at the spot, repaired, and spliced as usual; thus, by a single cut or splice, the fault is removed. Hitherto, to find such a fault, it has been necessary to cut and splice the cable in many places before the locality of the fault was traced out. A splice takes from 2 to 10 hours to make, and frequently wastes from 20 to 30 or more feet of cable, besides causing great delay, expense, and injury. When the currents are feeble we apply many probes, extending over 12 or 20 feet of the cable; their combined action gives greater deflection to the galvanometer. One foot length of probe is generally sufficient with moderate battery power, but when the cable exceeds 10 or 20 miles in length we use greater length of probe. Many other forms of probe may be used to effect this purpose. It is not absolutely necessary to complete the iron circuit by the piece *d*, Figs. 2 and 3, but so doing increases the power considerably. We generally use a reflecting galvanometer for showing the currents generated in the probe coils *c*, and we have made the following improvement in the galvanometer:—We make the reflector of hardened steel magnetised; this reduces the weight of it, which is considerable when a silvered glass is used with a magnet attached to it. When the defect is a break in the conductor, we first pass powerful currents from an induction coil or coils. These currents leap across the break in the conductor, and there and there only produce great heat, which melts the insulator, and so causes defective insulation at the spot. This effected, we proceed as in the

former case. When the defect is very small, and so offers much resistance to the passage of a current through it, the induction coil is used to burn it open, and so admit the water, and give free vent to the electricity. We then apply the probes, and discover the locality, and proceed as before described.

When the conductor under examination is simply a wire coated with an insulator and the conductor is broken but insulation sound, we apply currents of considerable tension to one end of the wire, and place an insulated conductor of electricity, such as metal tubes, foil, or place a portion of the wire under examination in a basin of wated insulated, the charge entering, the wire acts by electric induction on the outer tube, foil, or water; these latter act the part of the outer coating of a Leyden jar; these tubes, foil, or water, are connected with any apparatus suitable for indicating the presence of statical electricity of low tension, or they are connected with one of two conductors that are very near each other in a highly exhausted receiver, as Fig. 5 or 6; the other conductor is connected with the earth; the induced electricity will then be seen to pass between the two conductors in the vacuum. This outer covering is then moved along the insulated conductor, and the moment it has passed the fault where the inside tention terminates, the external electric indications cease and show that the fault has been passed.

When it is desirable not to damp the insulated wire containing a defect in its insulation, we sometimes put the whole coil into a large receiver and exhaust to a nearly perfect vacuum. Then on causing currents to enter one end of the wire they escape at the defect through the rarified air to the pump plate, and thus indicate at once by their luminosity the exact locality of the fault.

For the purpose of making the exhaustions it became needful to have a pump that may always be depended on to produce a sufficiently good vacuum. We have constructed one that will give the required vacuum, and is very little liable to derangement by use, and its parts are easily comeatable for cleaning or adjusting. The peculiarities of this pump are that it has a perfectly open and free passage from the receiver to the barrel when the piston is rising, and the same passage is perfectly closed when the piston descends without any valve, mercury being used to effect that purpose. The same liquid metal is placed at bottom of the barrel above the pistons, the valves, and joints, or fittings, to keep all air-tight; sufficient mercury is allowed to leak back through openings made for this purpose at every rise of the pistons and valves, in order that at every passage or escape of air there may be some mercury to follow out also, and so secure the total expulsion of all air.

For the sake of using mercury every part of the pump is made of iron, glass, or other suitable material. Figs. 7, 8, 9, and 10 show its construction

and action. *a*, *a*, the barrel; *b* and *c* the upper and lower portions of the piston, capable of sliding to or from each other; *d* and *e* two upper valves; these four are all conical; *f*, the piston rod; *b*, the piston; *g*, *g*, two lifting rods which slide through the piston, but are jointed to the plunger *c* at *h*, *h*; *i*, *i*, a circular spring to make the rods slide with friction; *j*, *j*, the long narrow passage from the barrel *a* up to the receiver or pump plate, 32 inches or more in height; the weight of this column always balances the atmospheric pressure, and so keeps the passage closed without any other valve.

In Fig. 8 the piston *b* is nearly up, when it began to rise it lifted the plunger *c* just enough to leave room for the mercury to flow down from the tube *j* into the space *k*, and so leave the passage *j* open; air from the receiver then freely follows the piston when the piston begins to descend; its first act is to push the plunger *c* into the mercury *k* and spread it above the hole *j*, and close it up; on the farther descent of the piston the mercury rises in *j* till it balances the pressure. The piston leaves a vacuum behind it, so the air below more readily rushes past the valve *l* (which is an iron flap and under mercury) into the vacant space, and is followed by some of the mercury. Every crevice below the piston is filled with mercury, so there is nothing left to expand when the piston again rises; the top of the piston is well flooded with mercury. On its rising the cone of the valve *d* dips first in the middle, and the mercury gradually rises to the circumference and drives all the air before it past the margin of the valve; at this instant the upper valve *e* floats a limited way in the mercury which is all round and over it, so it causes a perfect exclusion of air and leaves nothing but mercury above the piston. The piston *b*, when up at the top, has lifted both the valve *d* and the valve *e*, whose play is limited by stops *n*, *n*. On its redescending, the valve *e* first rests on its seat, and as the piston and valve *d* descend, they leave a vacuum between *d* and *e*, which causes what air adheres to the mercury to expand into the space between *d* and *e*, on the further descent of the piston the valve *d* rests on its seat, shutting off from the piston any so expanded air, and thus the further descent of the piston leaves a very complete vacuum behind it to receive the air and mercury from below, which rushes past the piston on its nearing the bottom, the mercury driving all air (and moisture when there is any) before it through the valve *l*, *m*. When the pump is double-barrelled each barrel has a separate tubular passage *j*, *j*, 32 or more inches high.

Fig. 9 shows the spring ring *i*, *i*, in top of the piston *b* to act against the rods *g*, *g*; *l*, the flap valve having enough play under its screw head; *m*, entrance from the under margin of *b* to the valve *l*.

Fig. 10 the plunger *c*; *h*, *h*, screws which fasten the pins of the rods *g*, *g*.

Fig. 11, the mode of checking the ascending mercury at any required height; a conical valve *o* is kept down by a weight *p*; when the mercury rises high enough to float this weight the valve *o* checks or slackens its farther progress. This is not generally necessary.

When a conductor is broken and we wish to ascertain the approximate distance of the break without burning open the insulator, or where this cannot be done, we measure the distance by the amount of induction in the following way:—A rheostat or bobbins of resistance are prepared free from magnetic induction or retardation; this we effect by winding the rheostat with two or more wires, or a doubled wire, and cause the currents to flow in opposite directions round them an equal number of times. This removes the momentary irregularity of their resistance arising from magnetic induction. We prepare also a series of induction plates, whose action is similar to that of extensive Leyden jars of known and suitable dimensions; these induction plates are added to the coils of the rheostat, so as to give them induction corresponding in amount to that of an equal length of cable. The following example will explain their use.

Suppose a wire broken in the gutta percha, and thereby insulating perfectly, by passing the current of a battery round the wires of a differential galvanometer as much resistance and corresponding induction surface are added as shall produce equilibrium. This measures with tolerable precision the amount of induction or charge and discharge of the cable, and consequently the distance of the leak in the conductor. This can also be used to test the locality of a defect, which gives great resistance, but not complete insulation as before assumed. As these induction plates are bulky, we prefer winding our differential galvanometer with many wires, say 11. We then connect the cable to one wire, but the rheostat to 10, in one continuous circuit; the resistance of the latter is increased in proportion, i.e., 10 times, while the surface of the induction plates is reduced to one-tenth, and thus rendered less cumbersome and expensive. On making and breaking contact, if the inductive absorption of the cable tested be 10 times as great as that in our induction plates, while the resistance of the induction plate circuit is 10 ten times as great as the cable wire, the electricity rushing in to charge the cable will be 10 times as great as that into the induction plates, but as the latter circuit is of 10 times the resistance of the cable, the time of the chargings will be equal. Lastly, as the smaller charge or current circulates 10 times as often round the differential galvanometer coil as does the cable charge or current, but in an opposite direction, they exactly neutralise each other, and the needle

remains at zero. Thus, the inductive charge is measured, and the distance of the defect shown.

In testing for a defect in a cable with the probes, when out at sea, great difficulty is experienced from the motion of the ship and the feebleness of the currents, we obviate much of this by supporting the galvanometer or indicator on our sea table of the following construction. Fig. 12 explains the principle on which they are constructed. *a*, *a*, the table, having at its centre of gravity a point *b*, by which it stands in a cup *c*; this table when truly balanced will neither be twisted nor thrown out of its horizontal position by any motion of the ship. The table is retained in the horizontal position by means of short quickly oscillating pendula *d*, *d*, of which there are 3, 4, or more. The pendula *d*, *d*, are suspended from an imaginary plane or circle coinciding with and equidistant from the centre of gravity *b* of the table; these pendula hang somewhat like scale pans below their beam. From the pendula *d*, *d*, are springing connections *e*, *e*, *e*, *e*; the pendula being free to move in any direction. These springs bring and keep the table in the horizontal position; any motion sets them oscillating rapidly, and as their springs are feeble compared with the inertia of the table, no motion of the latter is perceptible. Thus, we get a steady table at sea. The pendula are as near as possible alike in time of oscillation, and are connected by a light frame (not shown in the Drawing, but easily understood), which merely secures their simultaneous action. "It must be borne in mind that cables are never repaired in rough seas, when such a table could not be used."

We propose, where necessary, to attach gyrascopes to the table, which may be kept in motion by a train of wheels. *f* is a terminal with platina wire insulated from the table, and dipping into the ring cup *g*, which is insulated from the post *h*, on top of which is the cup *c*; these cups *c* and *g* are partially filled with mercury. The currents from our probe travel as shown by arrows, viz., up the post *h*, through the cup *c*, the point *b*, and the terminal *i* to the galvanometer *j*; back again through the terminal and platina wire *f* to the circular trough *g*, and thence to the other end of the probe coil. *k*, a lamp, with a shade *l* to hide it from the screen *m*; its light after entering the galvanometer is thrown back by the reflector to the screen *m*, on which it forms an image or spot of light.

We prefer using two galvanometers wound in opposite directions and throwing two images near each other on the screen, and thus when a current is passing, their oscillations, due to the current, cause the little reflected images to approach or receed; thus the oscillations caused by the electric currents are

readily distinguished from those caused by the motion of the vessel. *n, n,* adjusting magnets to neutralize the earth's action, and so make the galvanometers much more sensitive. When we do not use reflecting galvanometers we use an ordinary astatic one, but as one impulse is seldom sufficient we reverse the connections of the galvanometer with the probe as often as we reverse the battery connections with the cable, and thus cause the alternate currents of the probe to circulate round the galvanometer in one direction, their combined action giving a larger deflection. These reversals are produced by any of the well known commutators. When using such an instrument at sea, we propose to station a clock, beating half-seconds, on shore at that end of the cable to make the reversals, and also a clock on board beating not quite half seconds; and thus there will be a given number of currents sent round the galvanometer in one direction, then a pause, followed by a reversal in the direction of the currents, then the slow oscillation of the needle from side to side will show the existence of currents.

The modus operandi at sea.—Suppose the cable broken, we first, by testing, get an approximation to the locality. Clocks with the reversing apparatus are then attached to one or both ends of the cable, we prefer the latter; in this case the clocks are constructed to send reverse or alternating currents from their batteries to the cable at unequal intervals, say, the one reverses the current at every half second, and the other at every second.

The ship is sent as near as possible to the estimated spot to grapple for the cable, when this is found and brought up it is often very taut. The sea table, &c., if lifted on to its post and adjusted, the probes are then applied outside the cable, when, by the speed of the oscillations of its needle, it is seen on which side of the break the ship is. The cable, with buoy attached, is then lowered, and the ship proceeds in the direction of the fault, grapples again, and applies the probes; this operation is repeated till the fault has been passed, which is shown by the oscillations coinciding with the other clock. The value of this will be apparent, since to splice a heavy cable takes from 8 to 12 hours, and consumes much cable.

When the cable contains a defect, but has not parted, it may be under-run, and the probes applied throughout this operation, when the passage of the fault through them will be instantly indicated. These probes are also useful in tunnels on lines, and elsewhere, to indicate the position of faults without cutting the conductor. When there is no iron covering, nor iron near the conductor, an astatic needle, in a case, is applied to the outside of it as shown in Fig. 13 a side view, and 14 a top view, 15 the astatic needle separate; and thus by the deflection of the needle the passage of a current is indicated;

or, if preferred, two batteries whose like poles are connected with the earth, are attached to each end of the defective wire. These cause currents to flow from each end towards the defect, and there escape. On applying the needle, or rather on placing the wire into the grove in the case the needle is deflected, and indicates the direction of the current. On passing the fault the direction of the current will have changed, and the needle will be deflected in the opposite direction. This apparatus enables us to pick out of a number of lines the one under test, and then to trace out its fault, without cutting either the insulating covering or the conductor. This is of much service in tunnels or street work where the copper wire is not covered with iron.

Where the conductor to be tested is not covered with any insulating medium, for example, a telegraph wire suspended in the air, I adopt the following plan of tracing out what in telegraphic phraseology is called an earth or a contact, when the same cannot be readily discovered in the ordinary manner by the eye. An astatic, or very sensitive galvanometer, is wound with thick copper wire, about No. 14 guage, the two ends of this galvanometer wire are connected to the line wire to be tested, as shown in Fig. 16, from 10 to 60 yards apart; any current passing along the line divides one part of it traversing the galvanometer, the remainder continuing through the line. In this way the direction of the passing currents are readily detected. If, now, a line have a leak (make earth), and this be not visible to the eye in the usual way, connect the line at each end to a battery so that similar currents, (say, positive ones,) enter the line and escape at the leak as shown Fig. 17, on applying the galvanometer the direction of the current will be indicated. This will show on which side of the fault the galvanometer has been applied. In this way the exact spot can be readily traced out. The strength of the current traversing the galvanometer is shown by the formula,—

$$i^1 = \frac{R}{R + r} i.$$

i current traversing the line before the galvanometer is applied, R resistance of the line included between the terminals of the galvanometer wire a and b Fig 16, r resistance of galvanometer, i^1 current traversing the galvanometer (or loop) circuit.

Claims.—We do not confine ourselves to the precise forms described, as the same effect may be produced by various other modifications.

We claim generally the means of discovering faults in telegraph cables or conductors covered with insulating media, without removing or damaging the external covering or insulating medium.

We claim the mode of testing for the locality of faults described in Fig. 1, whereby we are enabled to indicate almost the exact locality of a leak, even when the resistance of the fault itself varies very much under the operation of testing, and which variation would have given erroneous indications by the hitherto known processes.

The general arrangement of the probes as shown in Figs. 2, 3 and 4.

We claim the pump shown in Figs. 7, 8, 9 and 10; also the measuring the distance of a fault in telegraphic cables by the inductive charge and discharge by means of differential galvanometers and resistance coils; to each of which latter are attached induction plates to give them an inductive charge corresponding to an equal amount of cable.

We claim the sea table Fig. 12, which may be used for other purposes than those described.

The mode of tracing out defects as shown in Fig. 13, 14 and 15; and also that in Fig. 16 and 17.

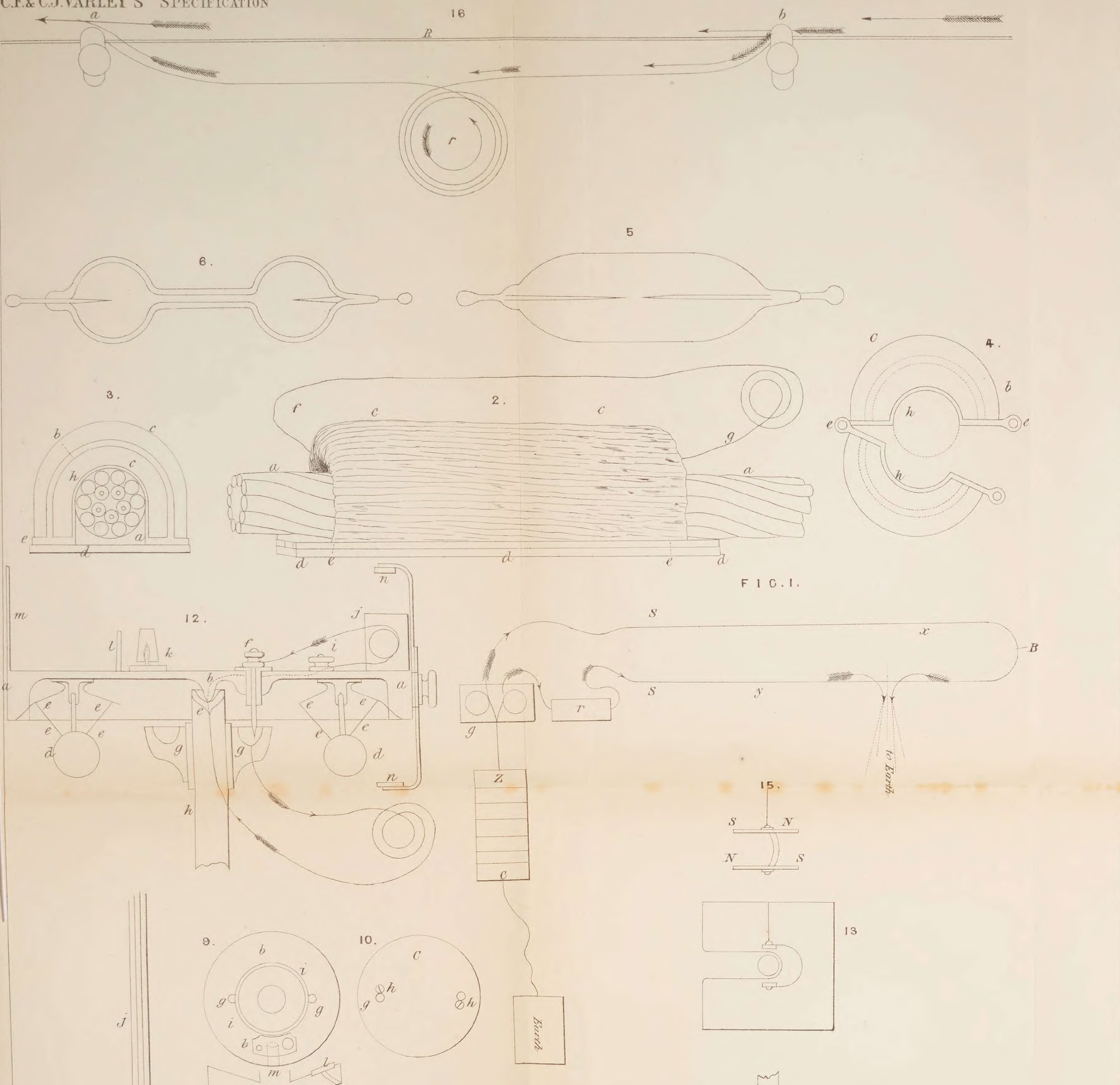
In witness whereof, I, the said Cromwell Fleetwood Varley have hereunto set my hand and seal, this Twenty-second day of December, in the year of our Lord One thousand eight hundred and fifty-nine.

CROMWELL FLEETWOOD VARLEY. (L.S.)

LONDON:
Printed by George Edward Eyre and William Spottiswoode,
Printers to the Queen's most Excellent Majesty. 1859.

A.D 1859. June 23. No 1509.
C.F. & C.J. VARLEY'S SPECIFICATION

(1 SHEET.)



The filed drawing is not colored.

Drawn on Stone by Malby & Sons

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